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Olkaria III Geothermal Power Generation Project - Kenya

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ABSTRACT

As global demand for electrical energy increases, nations worldwide are moving to cleaner and more reliable energy by developing geothermal resources and other renewable sources. The threat of global warming places an increasing demand for environmental compliance. Geothermal power generation provides low cost and reliable electricity, and in addition has immense benefits compared to the more expensive import-dependent fossil fuel plants. Not only that, but it also yields to the pressure to operate an environmentally benign system.

Orpower 4, Inc., operating in Olkaria III located in the Hells Gate National Park in the Rift Valley of Kenya, had to meet additional environmental requirements set by the Kenya Wildlife Services. The design and construction of the power plant had to integrate the park requirements, with the special needs of the animal population and maintain the delicate ecosystems, their associated life complexities and physical integrity.

The power plant was able to meet the required level of environmental compliance and generate electricity achieving over 98% availability. The system uses the organic rankine cycle to maximise the use of all available heat in the steam and liquid to generate electricity. The waste water is reinjected deep into the reservoir to replenish the aquifer, while the CO_2 is piped to a neighboring flower farm to enhance flower production. The construction of the early generation facility in phase I of the project in 2000 generated 12 MW of electricity and the recently completed phase II has achieved an additional 36 MW. Operation of the plant includes regular monitoring of the fauna and flora to ensure evironmental compliance, with regular quarterly meetings with the park authorities – Kenya Wildlife Services.

The project also benefits the local Maasai communities by assisting in the building of school infrastructure, enhancing the education of young girls and providing additional education and assistance to women's groups.

1. GEOTHERMAL RESOURCE FOR SUSTAINABLE DEVELOPMENT IN KENYA

Kenya has an estimated population of about 33 million of whom only 15% access to electricity. The rest depend on other sources mainly fuel wood and imported petroleum, whose environmental implications are felt globally. The electricity generated in Kenya is mainly hydro based with an estimated amount of 16% generated from geothermal energy. However, part of the country lies along the 'ring of fire' of the eastern Rift Valley which covers about a 1/3 of the total land area. It is rich in geothermal resources and the current potential estimate is over 1,500 MW. Exploitation of the resource is still minimal, but can be utilized to meet the national peak demand that now stands at 1,044 MW.

To date the main geothermal system in Kenya is in Olkaria where the Kenyan government's efforts to utilize geothermal resources dates back to the 1950s, when exploratory and drilling activities began. The region has been divided into seven sectors for development of geothermal energy – see Figure 1.

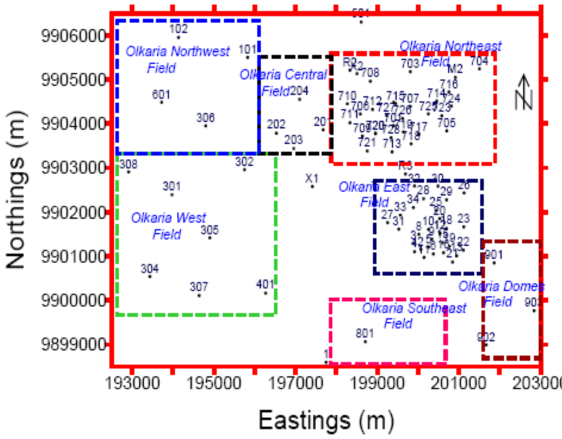

Figure 1: The seven blocks of Olkaria Geothermal Field.

The 1980s saw the establishment of the first geothermal power project at Olkaria I reservoir generating 45 MW, while Olkaria II has a power plant that generates 70 MW.

2. OLKARIA GEOTHERMAL RESERVOIR

The Olkaria geothermal reservoir is within the great Eastern Rift Valley, about 120 km northwest of Nairobi city. The area covers more than 80 km^2 and is rich in biological diversity, hence the establishment of the Hells Gate National Park in 1981 by the Kenyan Government. Lake Naivasha, a freshwater lake that gained international Ramsar recognition in 1989, and Mt. Longonot are major scenic sites within close proximity attracting both local and international tourism, education and research. The area has an immense geothermal potential as manifested in the numerous fumaroles next to Hobley's Volcano, sulphur deposits and steaming ground surface at Hells Kitchen among others. The challenge facing the Kenyan Government was to develop the geothermal resource for power generation while maintaining and sustaining the delicate biodiversity. The Hells Gate National Park covers an area of approximately 60 km^2 and is managed by the Kenya Wildlife Services – KWS. In managing the park KWS personnel monitor the patterns of animal movement and carry out seasonal animal census in addition to their regular research. It is with this environmental conservation concern that an international tender, supervised by the World Bank, was floated for the Olkaria West Field, commonly referred to as Olkaria III region. Orpower 4, a subsidiary of Ormat International Inc. was awarded the tender to develop the resource and build the power plant. An Environmental Impact Assessment of the project was carried out by Ormat in conjunction with KWS and key stakeholders. Key aspects that emerged and had to be taken into consideration included the delicate fauna, flora and the local community, including the stakeholders.

3. OLKARIA III PROJECT TECHNICAL DESCRIPTION

In phase I of the project a total of 9 additional wells were drilled and a 12 MW binary plant built and commissioned by year 2000. Within two years the initial output of 12 MW was optimisd to just over 13 MW. Phase II increased the capacity by a further 35 MW to bring the total electric power injected into the grid to 48 MW and includes a 7.5 km 220 kV power line that links the power generated to the the Nairobi North 220 kV circuits I and II. The generation of power from geothermal is achieved using Ormat's advanced air-cooled power plant technology where heat from the geothermal fluid is extracted from both the liquid and the vapor phase to an environmentally benign motive fluid that drives the turbines. This enables the system to maximise the heat resource available and allows us to even exploit the resources that have low enthalpy and/or high gas content. After heat extraction from the resource the cooled geothermal fluids are reinjected back without any water loss thereby enabling the aquifer to be replenished. The technology used has been developed by Ormat Technologies, Inc. and is used in plants producing over 1,060 MW located all over the world. Apart from the reinjection of the fluids at the Olkaria III plant the non condensable gases, which are 98% by weight of carbon dioxide, have been used to boost production of flowers at a the neighboring Oserian flower farm greenhouses. To date the Olkaria III plant operated by a team of local engineers has over the past 9 years achieved an average of over 98% availability. The electricity generated from the expanded power plant will save about 120,000 tons of imported oil, mitigate approximately 200,000 tons of CO_2 emissions per year and reduce the average production cost of electricity in Kenya while reducing its dependence on imports. Ormat's green technology meets the highest standards for sound environmental practice and complies with all of the relevant local and international regulations as acknowledged in the 2001 World Climate Technology Award from the UN Climate Technology Initiative (CTI). The application of this technology was fitting in the given circumstances where the need to manage the development of the geothermal resource against the delicate biodiversity balance in the national park was imperative.

4. THE ENVIRONMENTAL IMPACT ASSESSMENT

The challenge beyond generating electrical power was to ensure compliance to the environmental parameters initially set. The design team had to work closely with the KWS team to ensure that the design of the steam and brine pipeline routes were not only discrete but allowed for wildlife to continue with their natural migratory patterns. Other additional environmental concern issues were in compliance with the project EIA to minimize negative impact in the day to day operations and activities and monitor the status. They include:

4.1 Noise Emission

Noise emission is primarily from turbines and generators. Ambient levels at boundary points of the project area range between 30-40 dBA. The range is within acceptable international limits. Additional muffler jackets were prepared and used on the larger turbines. Regular monitoring of the noise levels at various points including the nearest residential houses is carried out every six months.

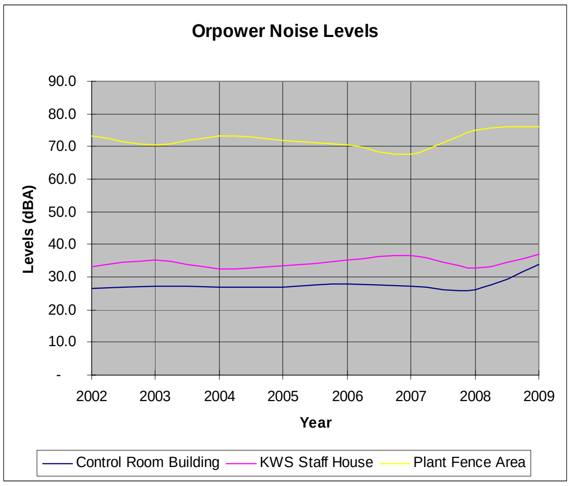

Figure 2: Noise level monitoring at various boundary project points.

4.2 Hydrogen Sulphide Emissions

Although the level of hydrogen sulphide in the non-condensable gases is less than 0.002% by weight, frequent monitoring of the levels at various locations is carried out. In addition we have installed a continuous monitoring unit accessible to the public. In all cases the levels were found to be below 0.03 ppm, hence within acceptable limits.

As a worst case scenario an analysis was done to simulate a dispersion of H_2S. These simulations were done using an Eulerian model. It is a three dimensional numerical model with non-terrain following mesh using the integral finite difference discretisation. It includes modules for transport (advection and diffusion), dry deposition, wet deposition and chemical transformation. The model can be used to determine the dispersion of any gas, both reactive and non-reactive. It can accommodate both continuous discharge and single puffs resulting from spillage accidents.

The numerical model uses C++ programming language to solve the mass balance equation. The language provides an object oriented infrastructure and was used to divide the geothermal field and its environs into a grid consisting of blocks and vertical layers. The size of the block is 250 m by 250 m by 2 m. With such a refined grid, hydrogen sulphide is assumed to have completely filled the block in six minutes, which is the time-step used in the model. After another time-step an equal amount of hydrogen sulphide is inserted into the model. The plume undergoes significant dilution within the source block, after which it undergoes diffusion and advection depending on the wind speed and direction. The location of the source block depends on the plume rise. The program then distributes the hydrogen sulphide from the source block to all the blocks and layers depending on the prevailing meteorological conditions.

4.3 Hydrogen Sulphide Concentration Predictions

The model was configured with three vertical layers each with 22×16 grid-points with a horizontal resolution of 250 m. The modeling domain was restricted to an area measuring approximately 11 by 7.5 km around the power station. The model calculates the concentration of hydrogen sulphide in the ambient air, based on emission estimates calculated using the emission from the cooling towers.

The source parameters include stack dimensions (12.6 m tall and 0.254 m diameter), amount of pollutant emitted (55 kg/hour and 100 kg/hr), temperature (80°C and 126°C) and velocity (21.33 m/s) at which the pollutant is emitted. Wind speed and direction, temperature, radiation and rainfall are the meteorological parameters.

Model-runs were made using input parameters averaged for the whole year. Figure 3 shows the near ground concentrations of hydrogen sulphide in parts per million. High concentrations are found within the vicinity of the power station. There is a significant decrease in the concentrations away from the source. The contamination is mainly concentrated within Olkaria West field with some encroaching on the Olkaria Northwest field. Generally, the concentrations range between 7 ppm around the power station and 0.5 ppm some 3 kilometers both to the North and East of the power station. The adjacent regions, especially to the east, presented insignificant levels of concentration, which can be attributed to dilution of the incident plume. The dilution effect tends to increase with distance so that H_2S concentrations are higher in the vicinity of the power plant than far away from it.

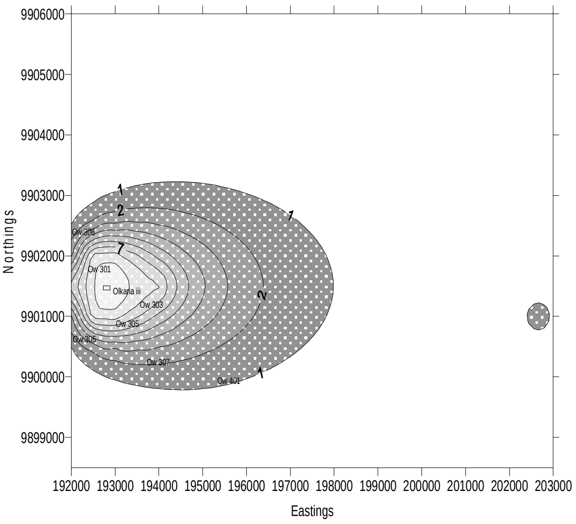

Figure 3: Simulated dispersion of a hypothetical hydrogen sulphide discharge at 6.5 kg per hour. The figure shows concentrations after 1 hour.

4.4 Soil Analysis

Regular monitoring of the soil and foliar is carried out every six months and analysed by accredited laboratories. The methods of analysis employed were in compliance with the Kenyan standards as administered by NEMA – National Environmental Management Authority, however where no national standards were available then suitable international standards were used. This was the case for analysis of volatile organic compounds as carbon tetrachloride where the standard from the Environmental Protection Agency of USA (EPA) was used in particular EPA 8240. The method utilises packed columns for gas chromatography and mass spectrometry in the analysis for carbon tetrachloride in the samples. Levels of arsenic, cadmium, boron and mercury are measured in control areas and selected areas. The results since early 2004 have shown no or slight deviation from control points in the analysis.

4.5 Vegetation Monitoring

Additional methods to improve the management of the environment have been introduced within the concession area. A sampling quadrant of 15 m^2 in area was established and the species counted to establish the representative species composition and the spacing of the individuals. The sampling quadrants established at different corners of the concession area provide useful data on the development of the various species and the relative increase in species in each quadrant, thus providing information on the growth rates by monitoring their counts, cover, height and basal expansion. The data taken from the control area was compared to that near the well pads where chances of contamination were higher. The dominant species are *Acacia drepanolobium*, indicator of rocky areas and *Tarconanthus camphoratus*, an indigenous invader species in dry areas. The resiliency levels of the two species are found to be beyond threshold levels, thus confirming limited or no negative effect from the project.

4.6 Animal Census

Orpower regularly assists the KWS wardens to carry out the wildlife animal census. This is done twice every year to cover the dry season and the wet season. The park is domicile to mainly the herbivorous animals such as *Thompson gazelles, impalas, zebra, buffalo and warthogs*. Deviation in population by the species is found to be seasonal and determined by food availability and animal behavior rather than project impacts. The park is not fenced and this allows the animals to migrate from within the park area and back. However, the lack of confinement also leaves the area vulnerable to pastoralists who invade the area during the drought season with their domesticated animals thus reducing the pastureland for the wildlife.

Other monitoring aspects include status of existing fumaroles, soil erosion, weather status and trends, volcanic/seismic/land subsidence. There has been no major change in the existing fumaroles attributable to the geothermal resource exploitation. The changes observed in the extent of steaming have been more related to the seasonal changes in weather patterns and perhaps attributable to the ease with which observations are made during the rainy seasons as compared to the dry spells. In this respect even the indicator species such as orchids seem to flourish and wilt in season with the climate. It should be acknowledged that only one year has elapsed since expansion of Olkaria III and perhaps the full effect of these activities is yet to be observed and monitoring of the various aspects needs to continue.

Further support to the KWS is in the form of an annual grant under a Memorandum of Understanding signed between KWS and Orpower 4, to fund conservation efforts that include research, outreach environment educational efforts to both park visitors and the neighboring communities, and other related issues within the Hells Gate National Park.

4.7 Corporate Social Responsibility (CSR)

The project has developed a CSR program that targets the peripheral agro pastoral Masai community. Support goes to school infrastructure, including school feeding programs, female child education, youth development programs and women's groups for improved standards of living. To date a total of 15 students are sponsored annually for further education beyond the level of the government sponsored free education. Over 70% of those sponsored by Orpower 4 are girls. The outcome over the years has been positive with some of the initial group now pursuing University education.

Other support focuses on Hells Gate National Park's coordination efforts with other environmental organizations within the Lake Naivasha catchment area.

5. CONCLUSION

Kenya is endowed with geothermal resources, a clean and sustainable source of electricity that can be sustainably utilized to curb the menace of power shortages. This is an appropriate option to reduce the importation of hydrocarbons, reduce global warming, ozone depletion, desertification, improving agriculture and providing the local population with livelihoods.

Currently the total generation from Olkaria stands at 165 MW. The challenge is to develop the balance of the resource in a responsible manner by selecting suitable technology that focuses on not only generating electricity but provides a sustainable means of managing the environment.

In line with the current global concerns Olkaria III has successfully applied for carbon credit registration for the current project; however it will take greater effort for governments and those in responsible decision making positions to reverse or even minimize the effect of global warming.

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